SMALL MAMMALS IN MONTANE ECOSYSTEMS OF THE NILGIRIS, SOUTHERN INDIA: THEIR ECOLOGY AND NATURAL HISTORY[1]

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Key words: rodents, *Rattus rattus*, *Millardia meltada*, montane forest, grassland, plantation

Small mammals were studied in the montane ecosystems of the Nilgiris in the Western Ghats, southern India, from February 1994 to September 1996. A total of 35,000 trap-nights were sampled in various habitats including montane forests, grasslands, and man-made habitats such as *Eucalyptus*, *Pinus* and *Acacia* plantations. A total of nine species were trapped in the montane forest patches and three to four species in each of the other habitats. *Rattus rattus* was dominant in the montane forests, while *Millardia meltada* was dominant in the grasslands. Both species were found in plantations. The occurrence of *M. meltada* in the high altitude grassland is remarkable, as it is not found in such habitats elsewhere, nor is it found in intermediate habitats in the Nilgiris. Species richness and abundance of small mammals was high compared to other natural habitats in southern India. While various aspects of the demography, habitat utilisation and community structure were studied, many others, regarding small mammal population dynamics, which are pertinent to their conservation and that of their predators, still need to be addressed with extensive field studies. Though this particular field is in its infancy in India, it is hoped that this and other such studies will pave the way for more such work in the future.

INTRODUCTION

Small mammals have been studied extensively, including aspects of life history (see Fleming, 1979 for review) demography (Fleming 1975), insularity (Gliwicz 1980; Adler and Levins 1994), desert communities (Kotler and Brown 1988; Brown 1989), competition (Grant 1972) and habitat utilisation (August 1983). However, they have been largely ignored in India except in taxonomic accounts (Agrawal and Ghose 1969; Biswas and Tiwari 1966; Chaturvedi 1966; Ellerman 1961; Ellerman and Morris-Scott 1951; Ghose 1964), surveys and pest management studies in agricultural areas (Barnett and Prakash 1975; Sood and Guraya 1976; Prakash 1976, 1988; Prakash and Ghosh 1992; Karim 1994). The lack of concern for murid rodents in particular is perhaps reflected in the Indian Wildlife (Protection) Act (1972) where this family (which includes most rodents apart from the giant squirrels, flying squirrels and a few others) is relegated to Schedule V (vermin) and reduced to two entries, namely 'rats' and 'mice'. There is, however, a fairly large body of work on the distribution of rodents in the country, largely due to numerous surveys by the Zoological Survey of India. Notable amongst these is the pioneering work of Dr. Ishwar Prakash (Central Arid Zone Research Institute, Jodhpur) which includes extensive studies on the Indian desert gerbille *Meriones hurrianae* (Prakash 1964, 1969, 1981; Prakash *et al.* 1965; Prakash *et al.*, 1969; Prakash and Jain 1970; Prakash and Idris 1992), ecology of rodent communities in various ecosystems in northwestern India (Agrawal and Prakash 1992; Prakash 1975, 1994; Prakash and Gupta 1976; Prakash and Rana 1973; Prakash *et al.* 1971; Prakash *et al.* 1996, 1995) and rodents as pests in agriculture (Barnett and Prakash 1975;

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Prakash 1976, 1988; Prakash and Ghosh 1992). The Rodent Newsletter of the All India Coordinated Research Project on Rodent Control (Central Arid Zone Research Institute, Jodhpur) has, since the mid 1970s, provided a forum for issues on rodents as pests.

Apart from these efforts, however, the available information about rodents in natural habitats is minimal throughout most of India. Interest in small mammal studies amongst wildlife biologists and animal ecologists in India gradually increased in the early 1990s. While the latter are interested in theoretical aspects of community ecology and population biology, the former are more concerned about the role played by small mammals in ecosystems, especially as prey of small carnivores, some of which are endangered. Chandrasekhar (1989) and Chandrasekhar-Rao and Sunquist (1996) studied small mammal communities in various habitat types in the Anamalais. Small mammal communities were also examined in the context of fragmentation of rainforests in the Western Ghats (Mudappa, pers. comm.; Prabhakar 1998) and in plantations in Kerala (Bhat and Sujatha 1986). Other recent ecological work includes studies on habitat utilisation in three rodents in sandy habitat in the Thar (Mukherjee 1999), and rodents as a prey base for small carnivores in Sariska Tiger Reserve (Mukherjee 1998).

I studied small mammal (rodent and insectivore) communities in montane (shola-grassland) ecosystems in the Nilgiris in southern India. The population dynamics and community ecology of small mammals have been dealt with extensively; I review these results briefly. Firstly, it is clear that density estimation methods have to be developed or modified with tropical forests and tropical small mammal populations in mind, especially when densities are low (Shanker 2000a). Alternately, one must focus on questions that do not deal directly with densities, but with other parameters that can be measured with precision in tropical systems. In examining the demography of small mammal populations in shola patches, a comparison between populations in small and large fragments showed that while population fluctuations between fragments were asynchronous, fluctuations within large patches were synchronous (Shanker and Sukumar 1999). This requires closer examination in the context of fragmentation in the Nilgiris and other parts of the Western Ghats. The demography and community structure of these small mammal populations was related to fragment size and habitat characteristics of the montane patches (Shanker and Sukumar 1998). Interspecific competition appeared to be less important than other factors such as intraspecific competition and predation (Shanker 2000b). Differences in small communities in different habitats and the significance of plantations in the landscape were examined and metapopulation processes and landscape effects on these populations in the montane ecosystem were explored (Shanker, in press).

Since small mammal community ecology is a relatively new field of study in the tropics, and India in particular, a great many questions remain unanswered. In many ways, this study threw up more questions than it answered. I attempted to address some of these questions with field and laboratory studies. In this paper, I give a brief overview of the small mammal study in the Nilgiris, with an emphasis on the natural history and ecology of the various species. I also present some hypotheses, and questions that remain unanswered during the study.

Study Area

The Nilgiris are located between 11° 10' - 11° 30' N and 76° 25' - 77° 00' E at the junction of the Eastern Ghats and the Western Ghats, in southern India. The study was conducted at higher altitudes (1,800-2,500 m above msl) of the Nilgiris which have a montane ecosystem, comprising of patches of stunted evergreen forest

(locally called 'sholas') surrounded by grasslands. Though most grasslands have been replaced by exotic species such as wattle (*Acacia* spp.), pine (*Pinus roxburghii*), tea (*Camellia sinensis*) and blue gum (*Eucalyptus globulus*), the natural ecosystem remains intact in the southwest region of the Nilgiris plateau. The stunted montane evergreen forest patches, usually 1-10 ha in size with few exceeding 100 ha, are confined to depressions and folds in the mountain. They are extremely dense, with 5000+ woody plants (>1 cm d.b.h.) per hectare, and are dominated by the families Lauraceae, Rubiaceae and Symplocaceae (H.S. Suresh and R. Sukumar, unpubl. data). There is a sharply defined ecotone between the montane forest patches and the grasslands that are maintained by frost and fire (Meher-Homji 1984). The climate is highly seasonal, with a dry season extending from December to February, a pre-monsoon season from March to May, the southwest monsoon from June to August and a second wet season from September to November. Most of the areas sampled receive annual rainfall of 1,500-2,000 mm.

Methods

Sampling Procedures

Live trapping of small mammals was carried out between February 1994 and September 1996. Montane forest patches and grasslands were sampled using 0.49 ha and 1 ha plots. Traps were placed at intervals of 10 m so that each 0.49 ha plot consisted of 49 permanently marked trap stations, in a square grid of 7 x 7 traps (the 1 ha plots had 100 trap stations, in a 10 x 10 configuration). Due to their size and shape, plantations were sampled using 0.45 ha plots (15 x 3 trap stations). A standard Sherman live trap (22.9 cm x 7.6 cm x 8.9 cm) was placed on the ground at each station, close to a tree, log, or any other appropriate runway. The traps were baited with grated coconut and rice. All trapped animals were identified, uniquely marked (Ear-punch, National Band and Tag. Co., Kentucky # 1538), sexed, weighed, measured and released. The traps were checked once daily between 0800 hrs and 1200 hrs. The plots were run for five consecutive nights during February-October 1994. Trap mortality was found to be particularly high towards the end of the trapping period in some seasons, and the trapping duration was thus reduced to three nights for the rest of the study (Shanker 1998).

Six montane evergreen forest patches, ranging from 2 to 600 ha, were extensively sampled using nine 0.49 ha plots and two 1 ha plots (see Shanker 1998; Shanker and Sukumar 1998). The sampling was primarily carried out in the Upper Bhavani region of the Mukurthi National Park and at Thaishola, about 20 km east of Upper Bhavani (which is about 65 km southwest of Udhagamandalam). Thaishola is the largest shola in the Nilgiris, (*c.* 600 ha) and the other sholas sampled ranged from 2 to 60 ha. Grasslands were also sampled using 0.49 ha plots. Both forest patches and grasslands were also sampled with 0.45 ha plots, which enabled comparisons with plots in anthropogenic habitats which had a similar design. Anthropogenic habitats - tea, gum, wattle and pine - were sampled using 0.45 ha plots, including wattle plantations of three different ages (Table 1). Additionally, a 0.90 ha plot was established in an old wattle plantation to study the interaction between *Rattus rattus* and *Millardia meltada*. Each plot was sampled several times, typically once during each season (= 'session').

Data Analysis

Various estimators were attempted using capture-mark-recapture models, but these could not be applied consistently to all species across all seasons (Shanker 2000a). Hence, we used the minimum number alive (Krebs 1966), which is the total number of animals of a particular species trapped during a trapping session.

Table 1: Trapping effort and habitat characteristics of the habitat types sampled in the Upper Nilgiris and Mudumalai Wildlife Sanctuary

Habitat	Plots	Sessions	Trap-nights	Canopy cover	Grass	Woody stems	Tree density	Height (m)
Grassland (0.45-ha)	9	19	3,486	Open	High	None	None	
Wattle - young	3	6	810	Open	Medium	High	None	3.2
Wattle - mid	1	4	540	Medium	High	High	Medium	4.1
Wattle - old	3	9	1,800	Closed	Low	Medium	High	9.9
Shola forest	15	89	*c.* 20,000	Closed	Low	High	Medium	11.5
Bluegum	2	6	810	Open	Low	Low	Medium	5.3
Tea	2	3	335	Open	Low	Medium	None	
Pine	3	10	1,350	Closed	None	None	Low	10.9

Results

In all, 1,310 individuals were trapped in the sholas, grasslands and plantations with an overall trapping success of 10.6%. A total of 9 species were trapped, there were 8 species in montane evergreen forests, 3 species in the grassland, 3 species in wattle, eucalyptus and pine plantations, and 4 species in tea plantations (Table 2). *Rattus rattus* was the dominant species in the montane forest and comprised 60.9% of the total density, while *Millardia meltada* was the dominant species in the grassland. In the natural habitat (forest and grassland), the two species are mutually exclusive. While the former was trapped in the forest patches, the latter was the only rodent trapped in the grassland. An analysis of wattle stands of different ages shows that *Millardia* dominates young stands (grass-like habitat), while *Rattus* dominates the older

Table 2: Average density (MNA/ha) of rodents and shrews in the various habitats in Upper Nilgiris

Species / Habitat	Thai-shola	Other Sholas	Grass-land	Wattle young	Wattle mid	Wattle old	Blue Gum	Tea	Pine
Rodents									
Rattus rattus	14.7	12.4	0	0	5.0	16.6	4.0	8.4	4.0
R.r. rufescens	-	-	-	-	-	R	-	-	-
Cremnomys blanfordi	S	-	-	-	-	-	-	-	-
Mus famulus	L	L	-	-	-	-	-	R	-
Mus platythrix	R	R	-	-	-	-	-	-	-
Platacanthomys lasiurus	L	R	-	-	-	-	-	-	-
Millardia meltada	-	-	9.6	6.6	25.5	8.3	7.7	2.0	2.6
Vandeleuria oleracea	S	-	-	-	-	-	-	-	-
Funambulus sublineatus	V	V	-	-	-	-	-	-	-
Ratufa indica	V	-	-	-	-	-	-	-	-
Shrews									
Suncus montanus	4.3	4.3	1.2	2.2	4.4	4.3	2.5	0.7	2.0
Suncus dayi	L	L	R	-	-	-	-	-	-
Feroculus feroculus	-	*	-	-	-	-	-	-	-

Thaishola is the largest shola in the Nilgiris at 600 ha. S – Single capture, R – rare species i.e. caught more than once, but only on a few occasions, L – low density i.e. caught during many trapping sessions, but usually only one or two captures during a session (density < 1 /ha), V – visual sighting, * – incidental capture

stands (forest-like habitat). *Suncus montanus*, a shrew, was the only species captured in both habitats. The other common species in the montane forest included *Mus famulus* and *Suncus dayi*.

The total density and biomass of small mammals were highest in the old and middle-aged wattle stands. While *Rattus rattus* accounted for the bulk of the density and biomass in the old stands, *Millardia meltada* was the dominant species in the middle-aged stands. Montane forests had intermediate densities and biomass, while grasslands had relatively low density and biomass. The density and biomass of the dominant species were substantially higher in some plantations than in the natural habitats. The density of *Millardia meltada* was significantly higher in middle-aged wattle stands than in grasslands, while the density of *Rattus rattus* was significantly higher in old wattle plantations than in montane forest patches. *R. rattus* attained a maximum density of 34 animals/ha and biomass of 3.3 kg/ha in November 1995 in an old wattle plantation. *M. meltada* peaked at 31 animals/ha (1.6 kg/ha) in June 1995 in a middle-aged wattle plantation.

Seven species of rodents (Order Rodentia) and two shrews (Order Insectivora) were captured during the study period (Table 2). Two other species of rodents were sighted, but not trapped. These included the dusky striped squirrel *Funambulus sublineatus*, and the Indian giant squirrel *Ratufa indica*. The latter is a much larger species and is not relevant to the study. Kelaart's long-clawed shrew *Feroculus feroculus* Kelaart, was caught once during preliminary trapping. This marks an extension of its territory from its previously known range (Pradhan *et al.* 1997). The small mammals considered here ranged in size from 6 to 206 gm, and could in theory have weighed up to about 300 gm, based on the size of the traps used. The suborder including rats and mice is the most widespread and has the largest number of species. Compared with other rodents, members of the Family Muridae (true mice) may have evolved most recently. One hypothesis suggests that murids evolved in southern Asia, as the earliest fossils of murids have been found in Pakistan. This would have been followed by adaptive radiation to the other continents.

***Rattus rattus* (Linnaeus) (Muridae)**

The most common and well known of murid rodents is the common rat *Rattus rattus*, also known as the black, roof, house or ship rat. *R. rattus* is found worldwide, and owes much of its ubiquity to accidental human introduction. While the brown rat *Rattus norvegicus*, has successfully colonised temperate countries, the black rat has invaded and is widespread in most tropical countries, including India. Ellerman (1961) divides the black rats broadly into two categories, the white-bellied form, which is usually found in the wild and the dark-bellied form, which is usually commensal with man; he further sub-divides them into 16 subspecies. The white-bellied form, which was trapped in many habitats in our study, was identified as *Rattus rattus wroughtoni* Hinton (Dr. M.S. Pradhan, ZSI, Pune, pers. comm.). It was trapped in natural habitats and in plantations. The dark-bellied subspecies *Rattus rattus rufescens*, which is usually found in agricultural fields, was trapped in wattle plantations. Both subspecies were trapped in the same area, raising questions about their relative taxonomic status. However, in another study, all white-bellied individuals collected from the Nilgiris were identified as *Rattus satarae* based on chromosomal, morphological and isozyme studies (Francois Catzeflis, pers. comm.). There are two separate issues here: are the different forms (subspecies) of *Rattus rattus* in fact separate species, as Catzeflis suggests? Does the *Rattus rattus* trapped in the Nilgiris belong to the species/ subspecies '*wroughtoni*' or '*satarae*'? Only extensive molecular genetic studies can provide

answers to questions surrounding the taxonomy of the various forms of *Rattus rattus* found all over India.

Rattus rattus is highly arboreal in the wild. The females are territorial, while the males appear to be free ranging. Each female occupies a nest on her own and has 3-4 pups. The adult is about 15-20 cm long with a tail that is 20-25 cm long; large males weigh about 150 gm, while adult females weigh 100-120 gm. Though males rarely weighed above 150 gm, a single individual weighing 206 gm was trapped once during the study. Interestingly, the white-bellied form of *Rattus rattus* (*wroughtoni*?) was also dominant in lowland evergreen forests in the Nilgiris (Meena 1997), Anamalais (Chandrasekhar 1989; Prabhakar 1998) and Kalakkad (Divya Mudappa, pers. comm.).

Millardia meltada Gray (Muridae)

Millardia meltada, the soft-furred field rat, found in cultivated fields throughout India (Prater 1988), has adapted successfully to the grasslands of the Upper Nilgiris. The general colour is pale brownish-gray, grayish-white on the underside. It has large rounded ears and a hairy tail, has a head body length of 13-15 cm, a tail nearly as long, and weighs 50 to 70 gm. This rat is commonly found in agricultural land and lowland plantations and is a major pest in many areas in north, central and southern India.

In natural habitat that was sampled in various studies in southern India, *M. meltada* was not trapped in the mid elevation forests or plantations in Kalakkad-Mundanthurai or Anamalais and in the mid elevation forests and grasslands in Mudumalai. Its occurrence in the high altitude grasslands of the Nilgiris is therefore a matter of some interest. It is also notable that it was not found in high elevation grasslands in Aravalli hills, though it was abundant at lower elevations (Prakash *et al.*, 1995). It is possible that this species colonized the Nilgiris grassland before the advent of man about 1000 years ago, and subsequently occupied the plantations about 200 years ago. Alternatively, it may have arrived as a commensal with man and colonized the grasslands subsequently. While there has been a long standing debate on the origin of the grasslands in the Nilgiris (Bor 1938; Ranganathan 1938) recent studies indicate that it is a climax ecosystem (Sukumar *et al.* 1993; Rajagopalan *et al.* 1997). It can therefore be expected that some rodent species would have occupied this habitat. Whether *Millardia meltada* is the original colonizer or a more recent one that arrived as a commensal can only be ascertained by paleontological or molecular genetic evidence.

Weight of animals in captivity

Fifteen individuals of *Millardia meltada* were kept in captivity. Within three to seven days of capture, 4 individuals gained weight at an average of 9.3% of their body weight, 5 individuals lost weight (7.8%), and 3 showed no change in weight.

Of 17 individuals of *Rattus rattus* that were kept in captivity, 15 (88.2%) showed an increase in body weight within three to seven days. Eleven of these showed an average increase of 3.14% per day within the first week, which would lead to an increase of about 20% within a week. The maximum increase was 40% of the body weight at capture in five days.

***Mus* spp. (Muridae)**

Bonhote's field mouse *Mus famulus* Bonhote is a small animal with a brown coat and a yellow underside. It is found at 1,507 m and above in the Nilgiris, and a few other hills in the southern Western Ghats. It is 5-8 cm long and weighs about 20 gm, and is probably less arboreal than the other rats and mice. It was found in areas of higher tree density in the forest patches (Shanker 2000b). The spiny field mouse *Mus platythrix* Bennett a species common all over India, is brownish above and white below.

Its fur is composed of flattened spines (Prater 1988). It was trapped in the two largest sholas in the first year of the study and was not trapped subsequently. Some information on the ecology of *Mus platythrix* and *Mus booduga* (Chandrahas 1974) is available; the brood of the latter has even been found in abandoned baya nests (Kichtar and Tiwari 1992)

***Platacanthomys lasiurus* (Muscardinidae) and other rare rodents (Muridae)**

Platacanthomys lasiurus Blyth is light rufous brown above and a dull white below. The muzzle is pointed, the ears are thin and naked, and the hind feet are broad and elongated. It is 13-20 cm long and weighs about 70 gm. The spiny dormouse inhabits rocky hills and forests at altitudes of 600 m and above. It lives mainly in the cavities of trunks and branches, and in clefts in rocks. The long tail, covered with hair, serves as a balancing organ for this highly arboreal animal. This species appeared after several months of trapping in the two largest sholas, Thaishola and the 60 ha shola. It was trapped only from September to January. There is little information on the distribution of this species, however, a number of new locales have recently been documented (Rajagopalan 1968; Jayson and Christopher 1995; Prabhakar 1997). This is the only endemic small rodent in the Western Ghats, the other endemic rodents being the grizzled giant squirrel (*Ratufa macroura*) and a flying squirrel (*Petinomys fuscocapillus*).

The white-tailed wood rat *Cremnomys blanfordi* Thomas is very similar to the common rat in appearance, except for the tail, which is brown for three quarters of its length, but white towards the tip. It is highly arboreal in forests, makes a large and untidy nest, and has a litter of 2-3 young. This species was represented by a single capture in Thaishola and is probably not common at higher altitudes. It was dominant in lower elevation Deciduous Forests in Mudumalai in the Nilgiris (Meena 1997).

The long tailed tree mouse *Vandeleuria oleracea* Bennett can be distinguished by the fact that the first and fifth toe on all four feet are partially opposable and have a flat nail instead of a claw. It is about 7 cm in length, with a tail that is slightly longer. It is an extremely attractive creature, with a reddish coat and white underparts. It was trapped only once during two years of trapping in the Upper Nilgiris.

***Suncus* spp. (Order Insectivora, Family Soricidae)**

Suncus murinus (Linnaeus), the common or grey musk shrew, is found all over India in all kinds of habitats, and is common in cities as well. It is about 10-12 cm long with a slightly shorter tail, and weighs about 20 gm. In the Nilgiris, *Suncus montanus* Kelaart, a similar looking shrew, is more common. *Suncus dayi* Dobson, a much smaller shrew, weighing just 6 to 10 gm, is also found in the Nilgiris. Shrews are highly aggressive animals and on occasions, when two shrews were caught in the same trap, one would devour the other. On one occasion, a shrew and a common rat (*Rattus rattus*) were released simultaneously from a trap, whereupon the shrew attacked the weakened rat and chewed off its ear. Shrews have been known to attack rats, and Prater (1988) suggests that presence of shrews in houses may deter rats. Saini and Parshad (1996) report the consumption of a gerbil by a shrew in a multi-catch trap. Shrews tend to die in traps as they have a high metabolic rate; also in this case, the food in the trap was usually vegetable matter such as coconut. The smaller shrew, *Suncus dayi*, was rarely captured live in the trap.

Discussion

Although 'small mammals' do not constitute a taxonomic entity, the term generally includes mammals from 2 gm to 5 kg (Bourliere 1975). Of the 4,200 odd mammal species, 90%

weigh less than 5 kg. Ten out of sixteen mammalian orders contain mostly small species. In fact, both in birds and mammals, the below 1 kg class embraces the most successful order: of some 8,600 species of birds, 5,100 belong to the Order Passeriformes; of the 4,200 mammal species, about 1,700 are rodents. In India, there are about 100 species of rodents, with about 25 species in southern India. Most studies have recorded relatively few species of small mammals (three to five) in each habitat (Chandrasekhar 1989; Meena 1997; Divya Mudappa, pers. comm.). Prabhakar (1998) trapped 7 species of rodents and 1 shrew in mid-elevation rainforests. In comparison, the species richness in the high elevation montane forests of the Nilgiris is high with 6 species of rodents and 3 shrews. In addition, the grasslands had one rodent species. Trapping success (10.6%) was also high compared to studies in south India, where trapping success was 5% or lower (Chandrasekhar 1989; Meena 1997; Divya Mudappa, pers. comm.). A pattern that seems to have emerged from these studies is that mid to high elevation evergreen forest fragments support the highest species richness and abundance of small mammals in natural habitats in southern India. Another clear pattern is the dominance of the white-bellied form of *Rattus rattus* (*wroughtoni* and/or others) in evergreen habitat at mid and high elevations (this study; Chandrasekhar 1989; Meena 1997; Prabhakar 1998; Divya Mudappa, pers. comm.)

There has been a long debate on the importance of competition in structuring ecological communities (Connell 1983; Schoener 1983). The distribution of *Rattus rattus* and *Millardia meltada* in this ecosystem is particularly interesting. They are completely exclusive in the natural habitat, which is particularly notable in the shola grassland system where there is a sharp ecotone between the two habitat types. *Rattus rattus* would be found till the edge of the shola and *Millardia meltada* till the edge of the grassland, and therefore within metres of each other, but never in the other habitat. Though this initially indicated some competitive exclusion, the two species coexisted in the plantations. The distribution of the species may thus have been influenced more by the habitat parameters, trees in the case of *Rattus rattus* and grass in the case of *Millardia meltada*. This is also supported by the fact that *Millardia meltada* is dominant in young wattle stands, which have more ground cover, while *Rattus rattus* is dominant in older wattle stands with taller trees (for details, see Shanker 2000b). Removal and introduction experiments in the montane forests and grasslands did not show any competition between the species (Shanker 2000b). While the evidence for competition between the species is low, it would be interesting to carry out reciprocal removal experiments in the wattle stands where the species coexist. Gut content analysis should provide some evidence on the feeding habits of the two species. Since one is a grassland species and the other a forest species, another method of studying differences in foraging would be to look at stable carbon isotopes in bone collagen (DeNiro and Epstein 1978; Sukumar and Ramesh 1992). Food choice experiments would also shed light on their feeding habits.

Small mammals such as rodents are considered to be especially important components of the ecosystem as they serve as prey for small and medium sized carnivores. In the Upper Nilgiris, potential predators include several birds such as raptors, owls and crows and several mammals such as jungle cat, leopard cat, small Indian civet, ruddy mongoose, jackal and Nilgiri marten (listed in Shanker and Sukumar 1999). Study of the demography of small rodents in the montane patches revealed some interesting patterns. The population of *Rattus rattus* in the smaller fragments was asynchronous, which may be due to predation and demographic stochasticity (Shanker and Sukumar 1999).

Further, population characteristics of small mammals were affected by patch size (Shanker and Sukumar 1998). Apart from *Rattus rattus* and *Suncus montanus,* the other species were not trapped during all trapping sessions in the forest plots. This indicates that some of these species might periodically go extinct in the smaller patches. These would thus be a good system for the study of metapopulation biology, especially in the context of the persistence of rare species in the patch network. The shola-grassland and shola-plantation habitats also provide different kinds of landscapes to study the effects of edge permeability and habitat connectivity on small mammal populations. The results show that plantations, especially old stands, have high small mammal densities. This could affect the population dynamics of small mammals in the forest patches. These factors need to be taken into account in the management of these areas, and may be important factors to consider in the conservation of predators that depend on these small mammals for food.

The theory of island biogeography (MacArthur and Wilson 1967) was extended to isolated habitats on land with a study of mammals on mountaintops (Brown 1971). Since there are certain patterns in insular small mammal populations in the Nilgiris, similar patterns may exist in other montane ecosystems in the Western Ghats. Other studies on fragmentation in southern India have found effects of insularity and patch size on small mammal communities in lower elevation evergreen forests (Prabhakar 1998). It is possible that the patterns observed in the Nilgiris may be generalised to montane systems in the Western Ghats. It would also be interesting to look at the montane systems of various ranges as islands and examine the impact of isolation on the small mammal communities of 'mountain tops'. One could also compare the distribution of *Rattus rattus* and *Millardia meltada* in the Nilgiris with other montane ecosystems.

The relationship between population synchrony and geographical distance was not clear at smaller spatial scales. One of the ways to study population structure is through molecular genetic analysis. Populations of *Rattus rattus* from several montane forest patches and *Millardia meltada* from grasslands in the same areas were studied using multilocus minisatellite DNA fingerprinting. Patterns of inter-individual and interspecific variation in these rodent populations were examined. Inter-individual variation in *Rattus rattus* was found, which could be used in population genetic analysis (Kartik Shanker, Anindya Sinha and Trupta Purohit, unpubl. Data). More data is required before patterns of variation and population structure can be discerned. Currently, molecular tools such as microsatellite analysis are widely used for population genetic studies and can be used to answer these questions.

It is clear that much work remains to be done on small mammals in tropical ecosystems. The montane ecosystems of the Western Ghats offer a fascinating landscape where ecological hypotheses of interest can be tested. It is hoped that future generations of Indian ecologists will address some of these questions.

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